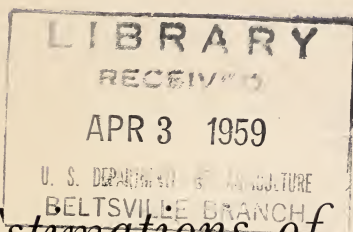


Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A 281.9
A 68
#25
Cap-1

Production Research Report No. 25



Estimations of

WIND ERODIBILITY *of* FARM FIELDS

EXTRA
COPY

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Kansas Agricultural Experiment Station

CONTENTS

	Page
Determining surface roughness.....	2
Determining crop residue.....	2
Determining soil cloddiness.....	3
Determining stability of surface crust.....	4
Determining natural wind erodibility and conditions required to reduce wind erosion to any degree.....	5
Interpretation and limitation of estimates.....	10
Literature cited.....	12
Appendix.....	13

Chepil, William S 1904—

Estimations of wind erodibility of farm fields, by W. S. Chepil and N. P. Woodruff, Agricultural Research Service, U. S. Dept. of Agriculture in cooperation with Kansas Agricultural Experiment Station. [Washington, U. S. Govt. Print. Off., 1959]

21 p. illus. 24 cm. (U. S. Dept. of Agriculture, Production research report no. 25)

"Literature cited"; p. 12.

1. Wind erosion. I. Woodruff, Neal P., 1919— joint
author. II. Title. (Series)

[S21.A] 551.37 Agr 59-68

U. S. Dept. of Agr. Libr. A281.9Ag8 no. 25
for Library of Congress

Washington, D. C.

Issued March 1959

Estimations of WIND ERODIBILITY *of* FARM FIELDS¹

By W. S. CHEPIL, soil scientist, and N. P. WOODRUFF, agricultural engineer,
Soil and Water Conservation Research Division, Agricultural Research Service

A method to estimate wind erodibility of field surfaces and to determine land surface conditions required to reduce it to any degree was presented in a previous publication (5).² The method was based on information obtained principally from wind tunnel tests (7, 8).³ It was not known whether the wind tunnel tests gave a true indication of natural wind erodibility of farm fields. A study was undertaken, therefore, to check the validity of the original method. On the basis of results obtained, a revised method to estimate natural wind erodibility of farm fields and to determine land conditions required to reduce it to any degree is presented. Revisions of the original method are few.

The revised method takes into consideration four principal factors that affect the natural wind erodibility of a land surface: (1) The surface roughness; (2) quantity of crop residue on the soil surface; (3) degree of soil cloddiness; and (4) stability of surface crust against disintegration by abrasive action of wind erosion.

The principal objectives and reasons for estimating wind erodibility of farm fields are: (1) To determine the potential wind erosion hazard in order to provide some basis for warning of probability of wind erosion during an oncoming windy season; (2) to determine the degree of surface roughness or soil cloddiness required in an emergency control program to supplement the amount of vegetative cover available on the land; and (3) to determine effectiveness of crop resi-

¹ Report of a cooperative investigation of the United States Department of Agriculture and the Kansas Agricultural Experiment Station.

² Italic numbers in parentheses refer to Literature Cited, p. 12.

³ See also—

CHEPIL, W. S., WOODRUFF, N. P., and ZINGG, A. W. FIELD STUDY OF WIND EROSION IN WESTERN TEXAS. U. S. Dept. Agr. SCS-TP-125, 60 pp., illus. 1955.

ZINGG, A. W., CHEPIL, W. S., and WOODRUFF, N. P. ANALYSES OF WIND EROSION PHENOMENA IN ROOSEVELT AND CURRY COUNTIES, NEW MEXICO. U. S. Dept. Agr. AGR-SCS-Albuquerque, N. Mex. M436, [59] pp., illus. 1953.

dues and tillage practices in providing protection against wind and the inherent susceptibility to wind erosion for different soils and physical conditions of the soils.

DETERMINING SURFACE ROUGHNESS

The degree of surface roughness depends on height, length, density, orientation, and quality of vegetative cover and on size, shape, and lateral frequency of clods, ripples, and ridges. It is extremely difficult to determine surface roughness by measuring these surface obstructions. For this reason, a "ridge roughness equivalent" was devised, based on the height of ridges composed of fine gravel 2 to 6.4 mm. in diameter and with a height-spacing ratio of 1:4, as determined in wind tunnel tests. For example, if the ridge roughness equivalent is 4 inches, the surface has a roughness and resists wind to the same degree as gravel ridges 4 inches high and 16 inches apart at right angles to the direction of the wind.

Measuring ridge roughness equivalent without a wind tunnel is almost impossible, but estimates can be made with reasonable accuracy from photographs of different field roughness for which the ridge roughness equivalent is known. Photographs have served as a standard guide for visual estimation of ridge roughness equivalent of field surfaces. These standard photographs (Nos. 1 to 18) are given in the Appendix (pp. 13-21), with a number that refers to ridge roughness equivalent, designated as K , in inches. The quantity of crop residue (R) above the surface of the ground also is indicated as supplementary data in each case.

DETERMINING CROP RESIDUE

Three 1-square-yard samples of crop residue selected at random appear sufficient in most cases to represent an average amount over the land. The residue on or above the surface is raked or cut off level with the ground and, together with any soil that may cling to it, is placed in a tray or sack and labeled. The residue is brought to the laboratory and the soil is shaken out thoroughly; or, preferably, the residue is washed on a 2-mm. (20-mesh) screen, and gravel, if any, is removed. The cleaned residue is dried in an oven and weighed. The weights are then expressed in pounds per acre. Weight of three 1-square-yard samples in ounces, multiplied by 100, equals the quantity in pounds per acre.

Where facilities are lacking, the amounts of residue may be estimated visually in a manner similar to that used for determining the ridge roughness equivalent (K). Standard photographs indicating different amounts and kinds of crop residue would facilitate the estimates (δ).

DETERMINING SOIL CLODDINESS

The percentage of surface soil material larger than 0.84 mm. in diameter, as determined by dry sieving, influences the amount of erosion of soil by wind (2, 4). Although this fraction is not the only soil factor that influences wind erodibility, it is by far the most important. A technique for sampling the soil and sieving it on an automatic rotary sieve has been described (1).

A hand-rotating sieve, such as that shown in figure 1, may be used

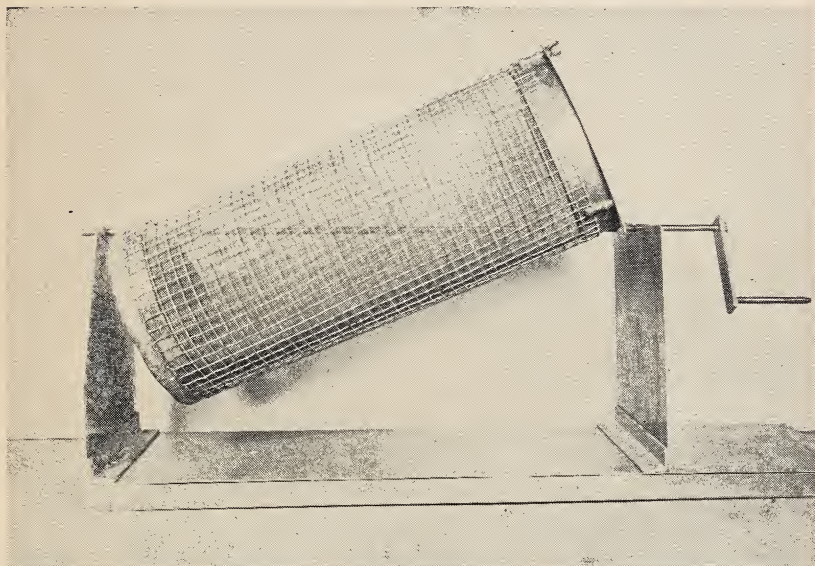


FIGURE 1.—Rotary hand sieve for use in the field. The cylindrical sieve is 20 inches long and 8 inches in diameter, mounted eccentrically on a crank rod resting on a support base. The sieve has square openings 0.84 mm. in diameter. Metal screen of $\frac{1}{2}$ -inch mesh is wrapped around it for support.

conveniently in the field or laboratory. The results of sieving depend on soil moisture, size of sample, speed of turning, and number of turns. These factors must remain constant if results of sieving are to remain comparable to those obtained with the automatic rotary sieve. The following conditions must be adhered to when using the hand-rotating sieve:

1. Take at least 4 soil samples to 1-inch depth. Each sample should weigh 4 pounds (1,812 grams).
2. Sieve the soil only when it is air dry. If it is not dry, bring the soil to the laboratory, dry it, and then sieve.
3. Turn the sieve 2 turns per 5 seconds. Maintain this speed by checking the second hand of a watch while turning.

4. If the soil is sand, loamy sand, or sandy loam, turn sieve 5 times; if it is loam, silt loam, clay loam, or silty clay loam, turn 10 times; if it is silty clay or clay, turn 15 times.

The soil remaining in the sieve is weighed and expressed in percentage of total weight of soil.

A conventional flat sieve 8 inches in diameter may be used, but results with it are expected to be less accurate than with the hand-rotating sieve.

DETERMINING STABILITY OF SURFACE CRUST

The original method to estimate wind erodibility was based on the amount of loose soil material that was blown in a wind tunnel under a certain wind. Owing to the relatively short length of tunnel (30 feet), the erodible soil material was blown off the test area without causing an appreciable amount of abrasion of the surface crust. Erosion ceased as soon as loose and fine soil particles were blown off. This seldom happens under natural conditions in the field, especially if the soil is sandy and subject to disintegration by the cutting or abrasive action of loose material blown along the surface by the wind. In the field, once erosion starts, it usually continues and actually increases in intensity with distance downwind and with each subsequent wind (4). The effects of abrasion are appreciable. Loose material travels long distances and cuts into the surface crust, thereby creating more and more erodible material that in turn is carried by wind. Fine sand is most susceptible to this cumulative abrasive action, because it does not have enough silt and clay material to cement the sand grains together. The surface crust in sand is exceedingly fragile and disintegrates readily under abrasion. Following fine sand in order of diminishing susceptibility to abrasion are loamy sand, clay, sandy loam, silty clay, loam, silt loam, clay loam, and silty clay loam.

Although stability of surface crust had an appreciable influence on wind erodibility, it was too fragile to influence soil cloddiness as determined by dry sieving. Therefore, soil textural class was used as an index of resistance of surface crust to disintegration by erosional abrasion such as occurs under field conditions (4). The soil textural class can be determined by conventional methods.

The surface crust is formed on freshly cultivated land with as little as one-fourth inch of water from a single rain. A crusted surface condition is therefore common on cultivated land.

DETERMINING NATURAL WIND ERODIBILITY AND CONDITIONS REQUIRED TO REDUCE WIND EROSION TO ANY DEGREE

Field studies during 1949-57 (4, 5, 7, 8)⁴ have indicated that wind erodibility of field soils as measured by wind tunnel techniques is described by a relationship of the following form:

$$X = a \frac{I}{(RK)^b} \quad (1)$$

Where X = wind tunnel erodibility in tons per acre

I = soil erodibility index based on percentage of soil fraction greater than 0.84 mm. in diameter

R = amount of crop residue in pounds per acre

K = ridge roughness equivalent in inches

a and b = constants whose values depend on past erosional history, type of residue and roughness, and condition of the surface crust.

The alinement chart in figure 2, in combination with table 1, permits a convenient partial solution of this equation and is all that is required for estimating natural erodibility from determined conditions of surface roughness, crop residue, soil cloddiness, and stability of the surface crust. The alinement chart has been revised to conform with additional data obtained in a wind tunnel, particularly on the general influence of soil cloddiness on erodibility by wind (4, *fig. 17*).

The soil erodibility index I of equation 1 is a convenient expression of wind tunnel erodibility on a dimensionless basis. It is equal to X_2/X_1 in which X_1 is the quantity eroded when the soil contains 60 percent of clods greater than 0.84 mm. and X_2 is the quantity eroded under the same set of conditions from soil containing any other proportion of clods greater than 0.84 mm. in diameter. For any given soil the value of the soil erodibility index I will be about the same, irrespective of which tunnel or what size of soil sample is used in determining the erodibility. The relationship between the soil erodibility index I and percentages of soil fractions greater than 0.84 mm. in diameter is shown in table 2.

TABLE 1.—*Factors for conversion of wind tunnel erodibility to natural erodibility on a field-scale basis*

Soil textural class	Factor F
Fine sand.....	6
Loamy fine sand.....	4
Fine sandy loam and clay.....	2
Loam, silt loam, clay loam, silty clay loam.....	1

⁴ See also footnote 3, p. 1.

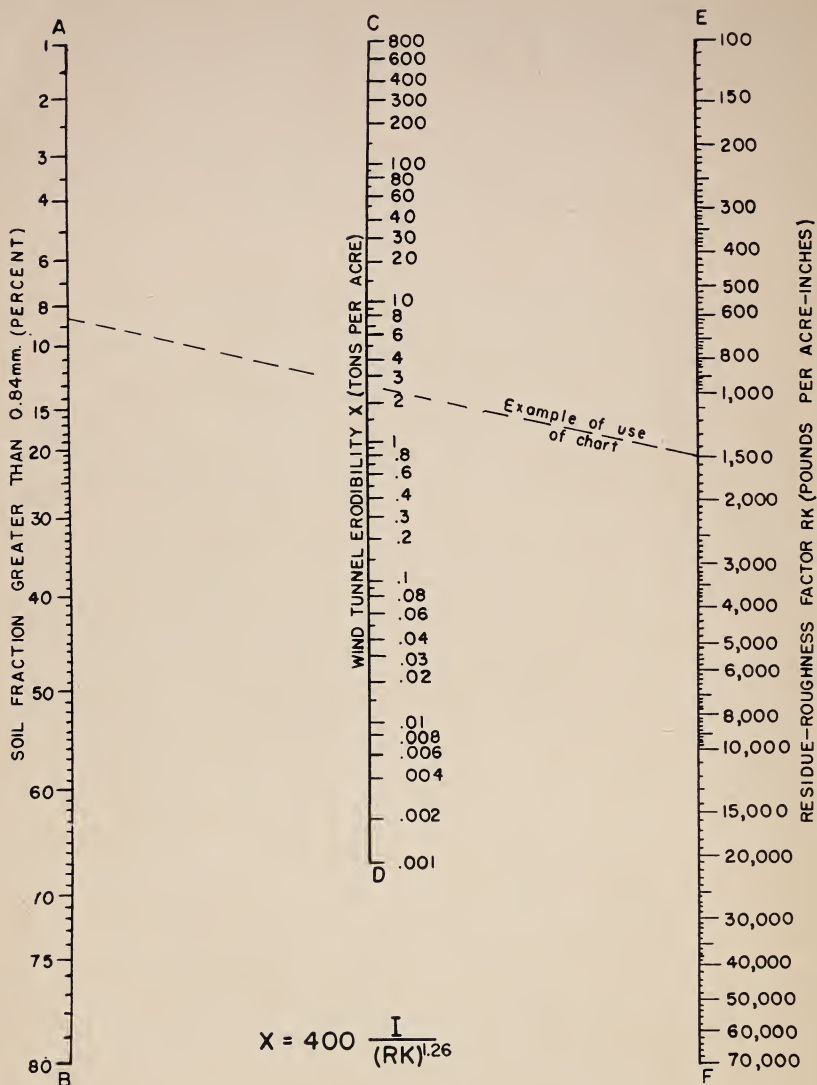


FIGURE 2.—Alinement chart for wind tunnel erodibility, based on crusted surface soil.

TABLE 2.—Soil erodibility index I based on percentage of soil fractions greater than 0.84 mm. in diameter as determined by dry sieving

Percentage of soil fractions greater than 0.84 mm.: UNITS → TENS ↓	9	8	7	6	5	4	3	2	1	0
9	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
8	.12	.14	.16	.20	.25	.30	.35	.40	.45	.5
7	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
6	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8
5	3.1	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.6	6.0
4	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.5	11.0	12.0
3	13	14	15	16	17	18	19	20	21	23
2	25	27	30	33	36	39	43	47	51	55
1	70	80	100	120	150	175	280	450	1,000	---
0										

The alinement chart of figure 2 is based on wind tunnel erodibility of a crusted surface. It conforms to equation 1, with constants a and b equal to 400 and 1.26, respectively. These constants differ considerably from those given in previous publications. The constants used earlier were based on wind tunnel tests carried out on soils having various erosional histories prior to the tests (5) and on soils that were previously subjected to a series of uniform erosive winds that had a variable influence on the surface crust, depending on soil textural class.⁵

The alinement chart of figure 2 is based also on average values for various types of crop residue rather than for some specific type. The values of wind tunnel erodibility for sorghum residue, for example, are somewhat low, owing to their relatively thick stalks. Also, the values for wheat residue are somewhat high, owing to the thin straw that, pound for pound, gives greater protection to the soil.

Wind tunnel erodibility (X), based on crusted surface soil, is read from the chart (fig. 2) as follows: A straightedge is passed through the percentage value of clods greater than 0.84 mm. on line AB and through the value of RK (the product of residue in pounds per acre and ridge roughness equivalent in inches) on line EF . The erodibility value corresponding to these conditions lies at the point where the straightedge crosses line CD . Thus, let it be assumed that the proportion of nonerodible soil fraction is 8.6 percent and the product RK is 1,500; then erodibility X read from line CD is 2.6 tons per acre. This example is shown by the dotted line in figure 2. Wind tunnel erodibility X is then multiplied by an appropriate factor F (table 1), depending on soil texture, to indicate natural erodibility as would occur under field conditions. If the soil is a fine sandy loam, the factor is 2 and natural erodibility is 5.2 tons per acre. If, on the other hand, the soil is a fine sand, the factor is 6 and natural erodibility is 15.6 tons per acre. Natural erodibility is defined as the relative amount of erosion resulting under field conditions from a comparable series of erosive winds. In this connection, $E=FX$, where E is natural wind erodibility, F is a factor listed for various soil textural classes in table 1, and X is the relative amount of soil eroded in a wind tunnel from a crusted soil surface.

The alinement chart (fig. 2), table 1, and figure 3 can be used similarly to determine the effect of given amounts of standing crop residue in reducing erosion. The procedure for doing this would be to determine the soil textural class and percentage of nonerodible soil fraction, estimate from the alinement chart the product RK required to reduce natural erodibility (the product FX) to any desired degree, and determine from figure 3 the amount of standing crop residue required.

⁵ Given in SCS-TP-125, listed in footnote 3.

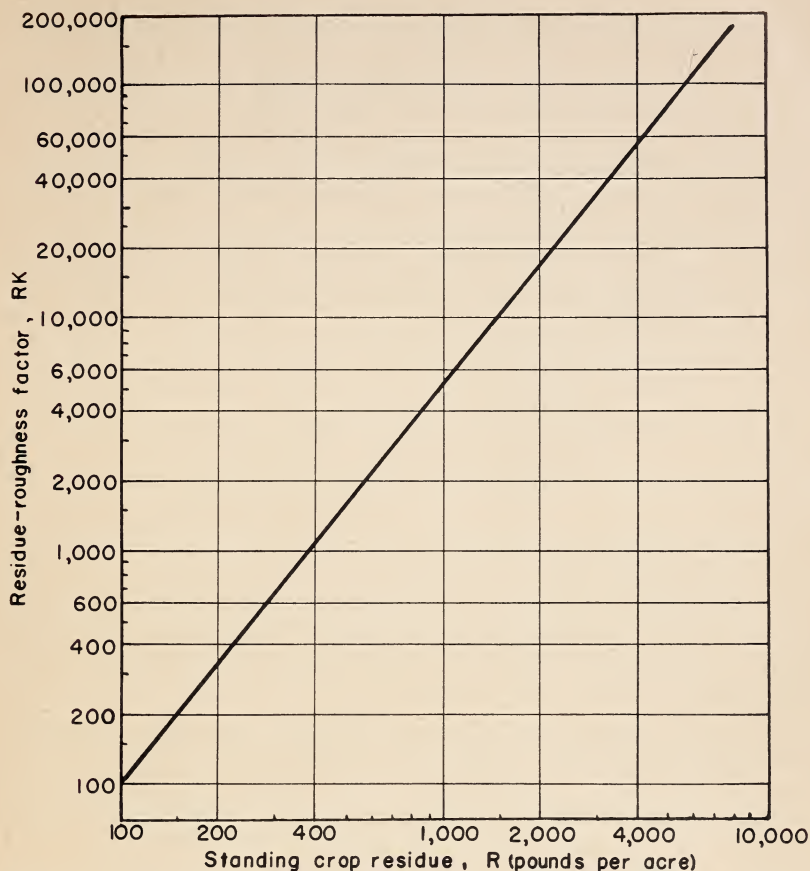


FIGURE 3.—Relationship of residue-roughness factor to quantity of residue on land untilled since the growth of the last crop.

For example, assume the soil is a fine sandy loam containing 8.6 percent of nonerodible fraction and that it is desired to reduce the natural wind erodibility to an insignificant amount of 0.25 ton per acre. For a fine sandy loam this value of natural erodibility is equivalent to wind tunnel erodibility X of $\frac{0.25}{2}$, or 0.125 ton per acre. A straightedge joining the value of 8.6 percent on line AB with 0.125 ton per acre on line CD indicates a required RK value of 20,000. Figure 3 indicates that the required quantity of standing crop residue for this value of RK is 2,200 pounds per acre. If, instead of a fine sandy loam, the soil textural class is a loamy fine sand containing the same proportion of nonerodible fraction, the desired erodibility X is $\frac{0.25}{4}$, or 0.062 ton per acre, the required value of RK is 32,500, and the required quantity of crop residue R is 2,850 pounds per acre.

The alinement chart (fig. 2) and table 1 also may be used to measure the effectiveness of tillage practices, such as listing or chiseling to provide protection from wind. The procedure in this case would be to carry out the practice, determine soil textural class and percentage of nonerodible fraction in the worked soil, measure residue, estimate K , and thus determine the natural erodibility from the chart and table. An estimate can be made of the approximate effect that tillage will have on natural wind erodibility. For example, assume the soil within 1 inch of the surface is a loamy fine sand containing 8.6 percent of nonerodible fraction, ridge roughness equivalent is 1.0 inch, and quantity of residue is 200 pounds per acre. The natural wind erodibility as determined from the chart and the table would be 125 tons per acre. Let it be assumed that listing of this same soil will change the texture at the surface to a fine sandy loam, increase the nonerodible fraction to 52 percent, increase the ridge roughness equivalent to 10 inches, and bury 100 pounds per acre of residue, leaving only 100 pounds per acre. The chart and table will consequently show the expected natural wind erodibility to be 0.3 ton per acre. Thus the lister, by bringing a finer textured soil to the surface, by increasing the proportion of nonerodible soil fractions, and by increasing the surface roughness, would reduce the natural wind erodibility from a very high value of 125 tons per acre to an almost insignificant quantity of 0.3 ton per acre.

INTERPRETATION AND LIMITATION OF ESTIMATES

A natural wind erodibility classification, based on the wind tunnel erodibility values of figure 2 in combination with soil textural factors of table 1, may be made as given in table 3.

The natural wind erodibility values serve merely as a relative measure of wind erosion. The quantity of soil eroded under any atmospheric wind force in the field varies with dimensions of the field, geographic location, and many other factors. Consequently, the actual quantities of soil moved by wind in a tunnel or in the field have little significance unless all the conditions that influence erosion are specified.

It matters little if natural erodibility is determined just before, during, or soon after the occurrence of one to several dust storms, because soil cloddiness, surface roughness, and quantity of crop residue change little from a series of windstorms. The immediate effect of wind erosion is on the surface crust. However, prolonged occurrence of erosive winds lasting a month or more tends to reduce the quantity of crop residue, soil cloddiness, and surface roughness. Therefore, a gradual deterioration in resistance of surface to erosion by wind may be expected. This deterioration may be detected with periodic estimates of natural erodibility.

TABLE 3.—*Natural wind erodibility classification*

Natural wind erodibility	Natural erodibility value (FX)	Basis of classification
Insignificant-----	Less than 0.25---	Soil has sufficient stable clods, ridges, or surface crust, or is sufficiently protected by vegetation to make it nonerodible.
Slight to moderate--	0.25 to 5.0-----	Soil is only partly stable and is only partly protected from erosion.
High to very high--	Greater than 5.0--	Soil is highly erodible and its surface is virtually unprotected from wind.

Soil cloddiness and, hence, natural wind erodibility change greatly from one season to another (3). Greatest breakdown in cloddiness and increase in erodibility are caused by freezing and thawing during the winter season. Cognizance of this fact should be taken when making estimates of natural wind erodibility. Estimates of natural wind erodibility resulting from different agricultural treatments are comparable only if they are all performed within a reasonable time or before drastic changes in natural erodibility occur.

The present estimates are based on average results obtained from wind tunnel tests and on quantities of natural erosion covering a wide range of soil textures, surface conditions, and quantities of crop residue. Quantities of crop residue required to reduce erodibility to any degree are standing crop residues, such as stubble or a growing crop undisturbed by cultivation. The natural erodibility values are applicable to fields having roughness, residue, cloddiness, and soil texture falling within limits shown on the alinement chart and table 1. These conditions can be evaluated by procedures outlined in this report. Some field experience may be necessary for making reliable estimates of these conditions, especially where visual estimates are used.

LITERATURE CITED

- (1) CHEPIL, W. S.
 1952. IMPROVED ROTARY SIEVE FOR MEASURING STATE AND STABILITY OF DRY SOIL STRUCTURE. Soil Sci. Soc. Amer. Proc. 16: 113-117, illus.
- (2) ———
 1953. FACTORS THAT INFLUENCE CLOD STRUCTURE AND ERODIBILITY BY WIND: I. SOIL TEXTURE. Soil Sci. 75: 473-483, illus.
- (3) ———
 1954. SEASONAL FLUCTUATIONS IN SOIL STRUCTURE AND ERODIBILITY OF SOIL BY WIND. Soil Sci. Soc. Amer. Proc. 18: 13-16, illus.
- (4) ———
 1958. SOIL CONDITIONS THAT INFLUENCE WIND EROSION. U. S. Dept. Agr. Tech. Bul. No. 1185, 40 pp., illus.
- (5) ——— and WOODRUFF, N. P.
 1954. ESTIMATIONS OF WIND ERODIBILITY OF FIELD SURFACES. Soil and Water Conserv. Jour. 9: 257-266, illus.
- (6) DULEY, F. L.
 1958. ESTIMATING CROP RESIDUES IN THE FIELD. U. S. Dept. Agr., Agr. Inform. Bul. 136, 31 pp., illus.
- (7) MAZURAK, A. P., ZINGG, A. W., and CHEPIL, W. S.
 1953. EFFECT OF 39 YEARS OF CROPPING PRACTICES ON WIND ERODIBILITY AND RELATED PROPERTIES OF AN IRRIGATED CHESTNUT SOIL. Soil Sci. Soc. Amer. Proc. 17: 181-185.
- (8) ZINGG, A. W.
 1951. EVALUATION OF THE ERODIBILITY OF FIELD SURFACES WITH A PORTABLE WIND TUNNEL. Soil Sci. Soc. Amer. Proc. 15: 11-17, illus.

APPENDIX

Guide for Visual Estimation of Field Surfaces



PHOTOGRAPH 1.—Loose, blowing sand, surface practically bare and smooth.

$K=1.0$ inch

$R=312$ pounds per acre



PHOTOGRAPH 2.—Smooth, fallow surface beaten down by rain, practically bare.

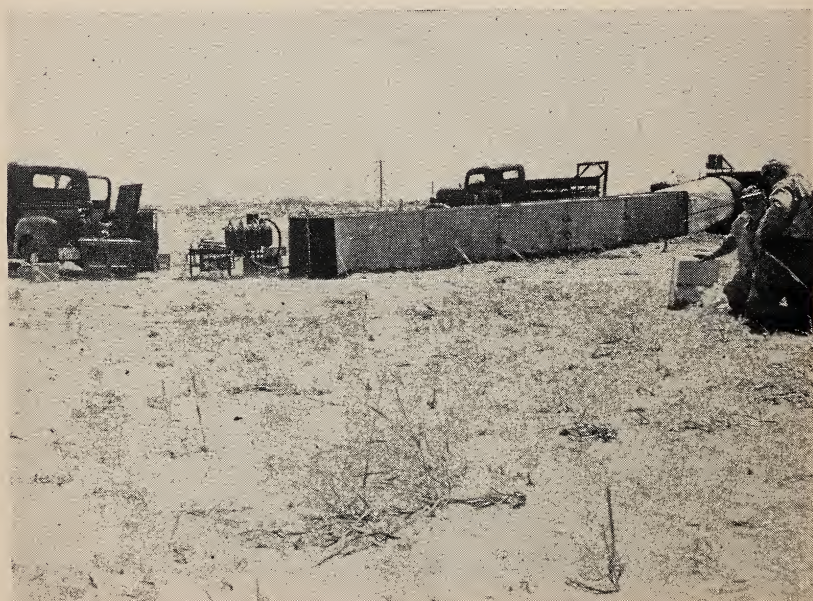
$K=1.5$ inches

$R=224$ pounds per acre



PHOTOGRAPH 3.—Good wheat residue cover, flattened down with one-way disk.

$K=1.6$ inches $R=425$ pounds per acre



PHOTOGRAPH 4.—Loose surface of loamy sand with some grass.

$K=2.0$ inches $R=311$ pounds per acre



PHOTOGRAPH 5.—Smooth surface with very sparse sorghum stubble.
 $K=2.0$ inches $R=400$ pounds per acre



PHOTOGRAPH 6.—Smooth surface with very short, thin sorghum stubble.
 $K=2.5$ inches $R=245$ pounds per acre



PHOTOGRAPH 7.—Semideep furrow drill ridges with some wheat stubble.

$K=2.6$ inches

$R=790$ pounds per acre



PHOTOGRAPH 8.—Good stand of growing wheat, about 3.5 inches high, slightly ridged by drill.

$K=3.2$ inches

$R=779$ pounds per acre



PHOTOGRAPH 9.—Heavy wheat stubble that was combined, partly flattened by one-way disk.

$K=4.0$ inches

$R=3,980$ pounds per acre



PHOTOGRAPH 10.—Recently plowed land with cloddy and moderately rough surface.

$K=4.0$ inches

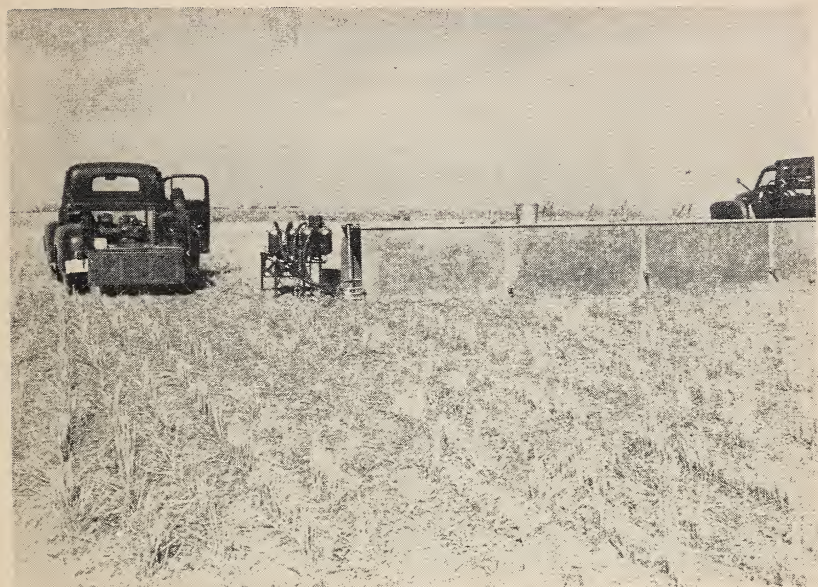
$R=100$ pounds per acre



PHOTOGRAPH 11.—Cotton, machine-stripped.
 $K=4.3$ inches $R=1,090$ pounds per acre



PHOTOGRAPH 12.—Sorghum stubble, cut with binder 5 to 7 inches high, 40-inch rows.
 $K=4.35$ inches $R=575$ pounds per acre



PHOTOGRAPH 13.—Wheat stubble, combined 8 to 10 inches high.
 $K=4.4$ inches $R=1,090$ pounds per acre



PHOTOGRAPH 14.—Sorghum stubble, chiseled, with some large clods;
considerable drifting.
 $K=4.6$ inches $R=640$ pounds per acre



PHOTOGRAPH 15.—Sorghum, combined 10 to 12 inches high, 40-inch rows.

$K=6.3$ inches

$R=1,220$ pounds per acre



PHOTOGRAPH 16.—Heavy sorghum stubble on irrigated land, thick and leafy, cut 8 to 10 inches high, 40-inch rows.

$K=8.5$ inches

$R=1,890$ pounds per acre



PHOTOGRAPH 17.—Listed, with little or no residue on top.

$K=10.1$ inches

$R=155$ pounds per acre



PHOTOGRAPH 18.—Milo on irrigated land, combined for grain, leaving 16- to 18-inch stubble.

$K=12.5$ inches

$R=2,275$ pounds per acre

